DATA EVALUATION RECORD

PC Code 128931 **Dicamba, DGA Salt**

Reference: Growe, Anthony M. 2017. Effects of Simulated Dicamba Drift on Maturity Group V and VI Soybean Growth and Yield. North Carolina State University, Raleigh, North Carolina, 114 pages

Test material: Clarity (Reg No. 524-582)

Common name: dicamba

Study classification: Supplemental

Primary Reviewer:	Chuck Peck EPA Reviewer	2018.10.31 14:20:18 -04'00' Date
Secondary Reviewer:	Frank Farrugia, Ph.D. EPA Reviewer	2018.10.31 14:22:28 -04'00' Date

Reviewer Conclusions

This research presented results of a literature review and two experiments in separate chapters. The focus of the review provided here is based on the research presented in Chapter 3 of the thesis.

The objective of this study was to evaluate the effects of sub-lethal rates of dicamba on five maturity group VI soybean cultivars at the vegetative and reproductive growth stages. Effects of dicamba were determined by collecting visual injury ratings, height reductions, and yield. The experiment was conducted in Lewiston and Kinston, NC in 2015 and Rocky Mount, NC in 2016, with a total of three site years. These locations were chosen to represent different growing environments, with Kinston having a Portsmouth loam soil and Lewiston and Rocky Mount having a Rains sandy loam. Five soybean varieties were treated with dicamba at 1.1, 2.2, 4.4, 8.8, 17.5, 35, and 70 g ae/ha (1/512 to 1/8 of the labeled use rate for weed control for dicamba-tolerant soybean) during the V4 or R2 growth stage. Experiments were conducted using a factorial arrangement of treatments in a randomized complete block design, with factors being dicamba rate, application timing, and soybean cultivar. Analysis showed a wide range of visual injury and height reductions 14 and 28 DAT (days after treatment) for all five varieties. Soybean heights were reduced and injury was greater as dicamba rates increased. Height reductions 14 and 28 DAT (weeks after treatment) were greater for the vegetative growth stage compared to the reproductive stage. Yield reductions ranged from 7 to 67% as dicamba rate increased from 1.1 to 70 g/ha. Analysis revealed a year, soil, variety, and timing interaction for yield reduction. At Rocky Mount and Lewiston, greater yield reduction was observed for the reproductive application but yield reduction due to application timing was not significant for Kinston. Although a variety response was observed for each trial, the results were inconsistent.

Comparison of the dose to injury and the dose to height effects for V4 stage plants supports a ratio of visual injury to height reduction of 2:1 (*e.g.* a 10% level of visual signs of injury corresponds to a dose that also produces a 5% reduction in plant height).

Materials and Methods

An experiment was conducted to evaluate the effects of sub-lethal rates of dicamba on five maturity group VI soybean cultivars at vegetative and reproductive growth stages. The design was a factorial arrangement of 80 treatments in a randomized complete block with four replications and three factors consisting of dicamba rate, soybean cultivar, and soybean growth stage. Trials were conducted at the Caswell Research Farm near Kinston, NC in 2015, the Peanut Belt Research Station near Lewiston-Woodville, NC in 2015, and the Upper Coastal Plains Research Station near Rocky Mount, NC in 2016 which represented three environments. In each trial, five soybean varieties, CZ 6316LL (Bayer Crop Science., Research Triangle Park, NC 27709) DG S64LS95 (Crop Production Services, Loveland, CO 80538), DG S69RY34 (Crop Production Services, Loveland, CO 80538), SH 6515LL (Meherrin Agriculture, Claxton, GA 30417), and SS 6810NR2 (Southern States Cooperative, Richmond, VA 23230), were selected from an initial test (data not provided) and planted using a two-row cone planter at a seeding rate of 350,000 seed/ha on 91-cm row spacing. After planting, flumioxazin (Valor SX, Valent U.S.A., Walnut Creek, CA 94598) at 71 g ai ha-1 was applied pre-emergent followed by two POST applications of glyphosate (Roundup PowerMAX, Monsanto Co., St. Louis, MO 63167) at 1260 g ae/ha or glufosinate-ammonium (Liberty, Bayer Crop Science., Research Triangle Park, NC 27790) at 590 g ai/ha to eliminate weed competition.

The diglycolamine (DGA) salt formulation of dicamba (Clarity herbicide, BASF Corporation, Research Triangle Park, NC 27709) was applied to soybean at 1.1, 2.2, 4.4, 8.8, 17.5, 35, and 70 g ai/ha (1/512 to 1/8 of the labeled 560 g ai/ha use rate for weed control in dicamba-tolerant soybean) when soybeans reached V4 (three completely unrolled trifoliates) or R2 (full bloom) growth stages. A non-treated control was included for each variety. Applications were made using a CO_2-pressurized backpack sprayer equipped with flat-fan nozzles (TeeJet XR 11002 VS, TeeJet Technologies, Springfield, IL 62703) calibrated to deliver 140 L/ha at 170 kPa. Weather conditions during each application were monitored and recorded using a Kestrel 3000 Pocket Weather Meter (Weather Republic, LLC, 3947 West Lincoln Highway, Suite 304, Downingtown, PA 19335). Plot dimensions were 3.65 m wide by 9 m long and consisted of four rows, with the two center rows being treated and two border rows to minimize cross contamination from herbicide applications. After each application, effects of dicamba were determined by collecting visual injury ratings at 7, 14, and 28 DAT using a scale of 0 (no injury) to 100% (complete death). Symptomology typical of auxin herbicides (leaf cupping, petiole epinasty, stem swelling, terminal bud death, and tissue necrosis) were factored into the injury rating. Soybean height was recorded 0, 14, and 28 DAT by randomly selecting four plants from each plot and measuring from the soil surface to the terminal bud. The treated rows for each plot were mechanically harvested and yields were adjusted to 13% moisture. For ease of comparison, plant heights and yield are expressed as a percent reduction of the respective non-treated check. All data were subjected to ANOVA using the GLM Procedure in SAS 9.3 (SAS Institute Inc., 100 SAS Campus Dr., Cary, NC 27513) and means were separated using Fisher's Protected LSD at p= 0.05. Regression analysis was calculated to determine the relationship between dicamba rate and each dependent variable. The relationship between visual injury, plant height reduction, and yield loss were examined using Pearson's correlation procedure in SAS. With the objective to understand how much dicamba is required to significantly reduce yield, treatments were compared to the non-treated using Dunnett's test at $\alpha = 0.05$ (Dunnett 1955).

Results

Soybean injury was evident at all dicamba rates and both application timings for all environments evaluated (Figure 4, 5, and 6). When dicamba was applied at 17.5 g/ha or less, visual injury ratings 7 DAT were less than 40% regardless of environment (Figure 4). However, differences in injury due to application timing were most evident for all environments at the highest dicamba rate, with greater injury in all environments observed when applications were made to R2 soybeans, regardless of dicamba rate. The injury observed when dicamba was applied to R2 soybeans continued to increase as time after application increased, with greatest injury occurring 28 DAT (Figures 5 and 6). However, when soybeans were treated at V4, injury was similar from 7 to 28 DAT, indicating more recovery compared to those treated at R2. Differences in injury due to application timing 28 DAT were more evident at Rocky Mount when dicamba was applied at 2.2 g/ha or greater (Figure 6). The greatest injury was observed at Rocky Mount and ranged from 19 to 83% when the application was made to R2 soybean compared to the V4 application which ranged from 17 to 54% (Figure 6). Similarly, injury 28 DAT for Lewiston was generally greater when dicamba was applied to R2 soybeans, which ranged from 18 to 75%, compared to the V4 growth stage which ranged from 5 to 48%. At the Kinston location, when dicamba was applied at 35 g ha-1 or less, injury 28 DAT was greater for the V4 application, ranging from 20 to 50%, compared to the R2 application which ranged from 13 to 46%.

Regardless of environment or application timing, height reductions 14 DAT were less than or equal to 20% when dicamba was applied at 2.2 g/ha or lower (Figure 7). Height reductions 14 DAT were generally greater for V4 applications compared to R2. At Rocky Mount and Kinston, differences in height reduction due to application timing were more evident once dicamba rates increased to 8.8 g ha-1 and greater. For Rocky Mount, height reductions were greater for the V4 timing ranging from 37 to 43% compared to the R2 timing which ranged from 22 to 37% (Figure 7). Similarly, at Kinston, greater height reduction was observed for the V4 timing and ranged from 35 to 60% compared to 7 to 17% R2 application. For the Lewiston location, separation between timings was observed at 35 g/ha and greater, with greater height reduction recorded for the V4 application. Trends in soybean height reductions 28 DAT were similar to 14 DAT (Figure 8). The greatest height reduction 28 DAT was observed after the V4 application in Rocky Mount and Kinston which ranged from 11 to 56% and 11 to 60%, respectively. Height reductions were generally greater for the V4 applications compared to R2 and can be attributed to the determinate nature of the varieties tested.

As dicamba rate increased from 1.1 to 70 g/ha, yield reduction ranged from 0 to 58% for the V4 application and 10 to 80% for the R2 application (Figure 9). These data suggest, when pooled across environments and varieties, that the reproductive stage is more sensitive to dicamba exposure than vegetative growth stages. Comparing among the three locations, the greatest yield reduction was observed at Kinston where yield reductions ranged from 10 to 80% as rate increased from 1.1 to 70 g ha-1 (Figure 10). At Lewiston, yield reductions ranged from 8 to 60%. Least yield reduction was observed at Rocky Mount, ranging from 1 to 62%. The lower yield reduction at Rocky Mount can be attributed to a planting date which was three weeks earlier than Kinston and Lewiston (Table #). When dicamba was applied at this location, soybean may have had more time to recover before maturity. When dicamba was applied at 8.8 g ha-1 (about 1/66th of the labeled rate for dicamba-tolerant soybean), yield reduction was 20% or greater for all environments.

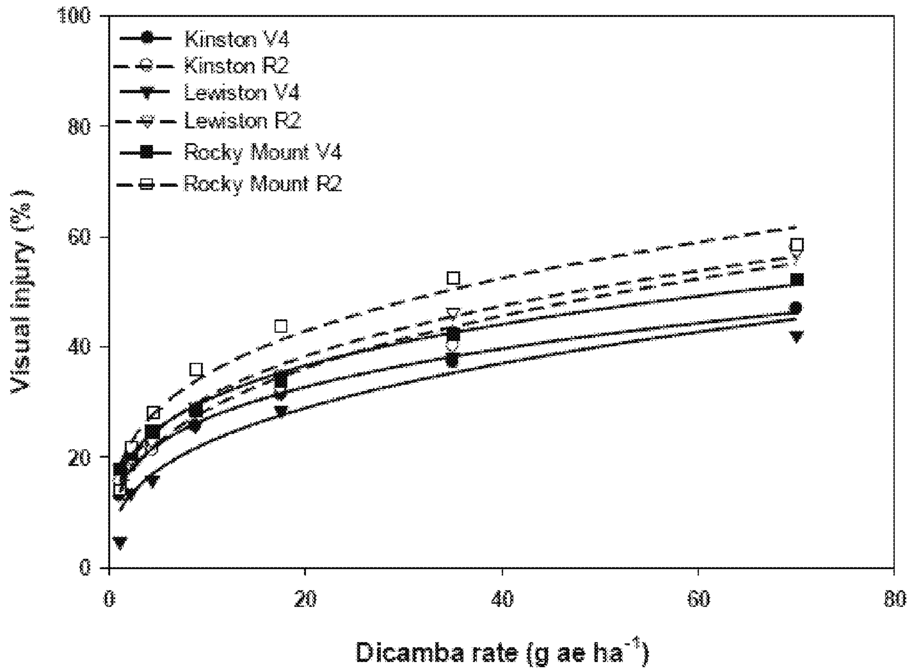

Figure 4. Soybean injury as affected by dicamba rate, application timing and environment 7 days after treatment (DAT). Predicted injury 7 DAT can be described as: Kinston V4: $Y= 14.3x^{0.27}$, $r^2=0.98$. Kinston R2: $Y=13x^{0.33}$, $r^2=0.97$. Lewiston V4: $Y=10x^{0.35}$, $r^2=0.93$. Lewiston R2: $Y=15x^{0.31}$, $r^2=0.99$. Rocky Mount V4: $Y=16x^{0.27}$, $r^2=0.99$. Rocky Mount R2: $Y=18x^{0.29}$, $r^2=0.96$.

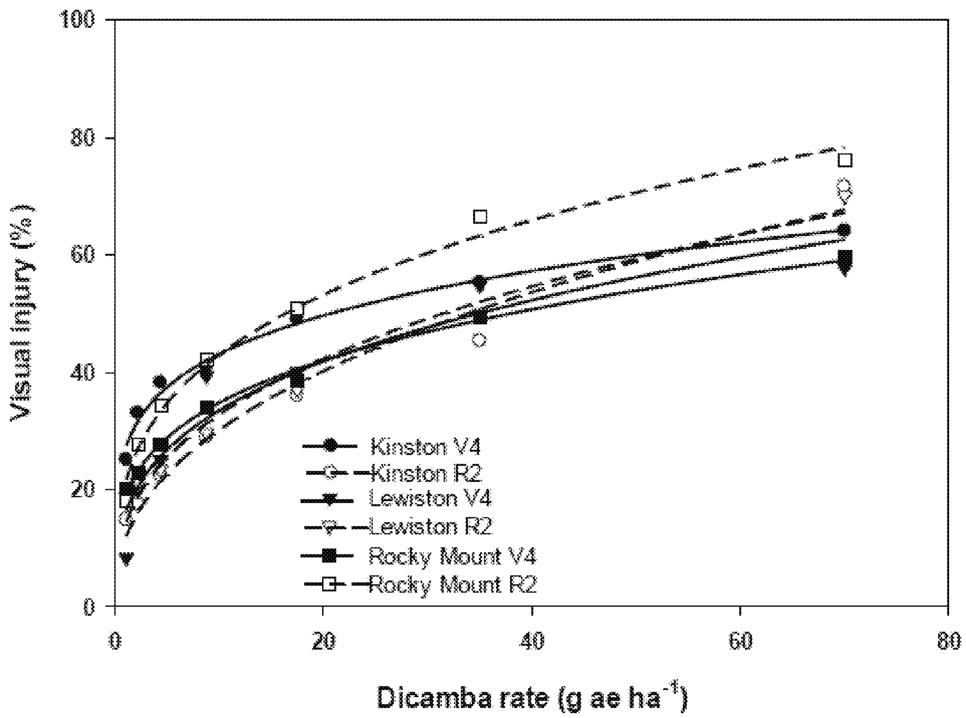

Figure 5. Soybean injury as affected by dicamba rate, application timing and environment 14 DAT. Predicted injury 14 DAT can be described as: Kinston V4: $Y= 27x^{0.20}$, r^2=0.98. Kinston R2: $Y=11.5x^{0.41}$, r^2=0.97. Lewiston V4: $Y=16x^{0.32}$, r^2=0.90. Lewiston R2: $Y=14x^{0.37}$, r^2=0.97. Rocky Mount V4: $Y=18.5x^{0.27}$, r^2=0.99. Rocky Mount R2: $Y=21x^{0.31}$, r^2=0.98.

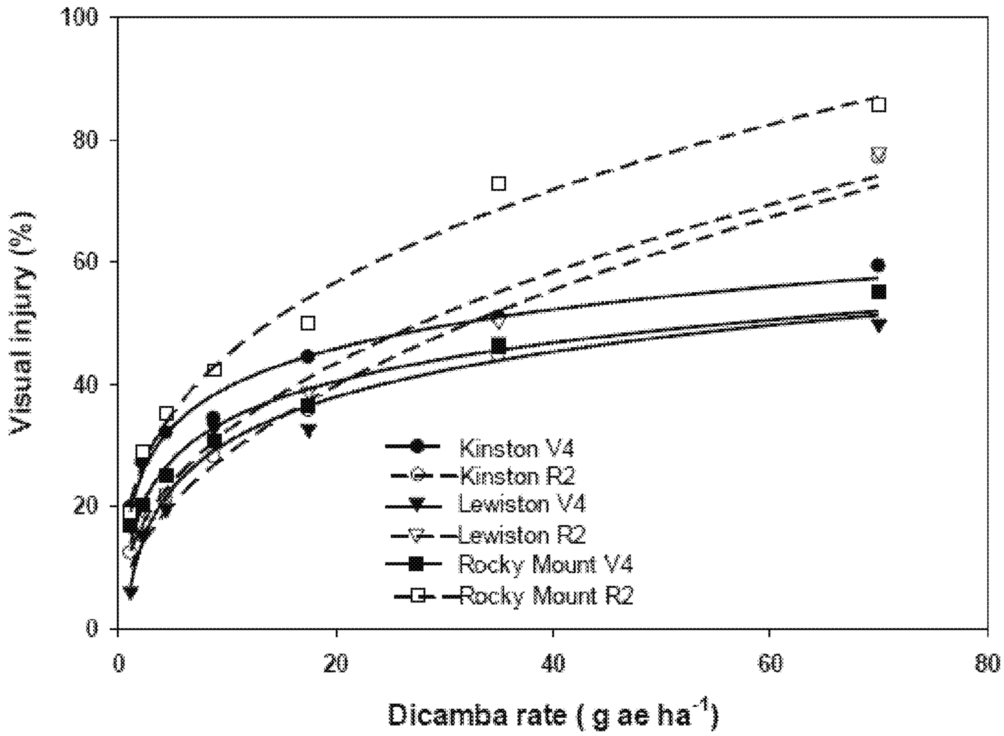

Figure 6. Soybean injury as affected by dicamba rate, application timing and environment 28 DAT. Predicted injury 28 DAT can be described as: Kinston V4: $Y= 18+9*\ln(abs(x))$, $r^2=0.98$. Kinston R2: $Y=5.8+10.7*\ln(abs(x))$, $r^2=0.96$. Lewiston V4: $Y=13+9.2*\ln(abs(x))$, $r^2=0.96$. Lewiston R2: $Y=20x^{0.34}$, $r^2=0.98$. Rocky Mount V4: $Y=9x^{0.48}$, $r^2=0.96$. Rocky Mount R2: $Y=12x^{0.43}$, $r^2=0.97$.

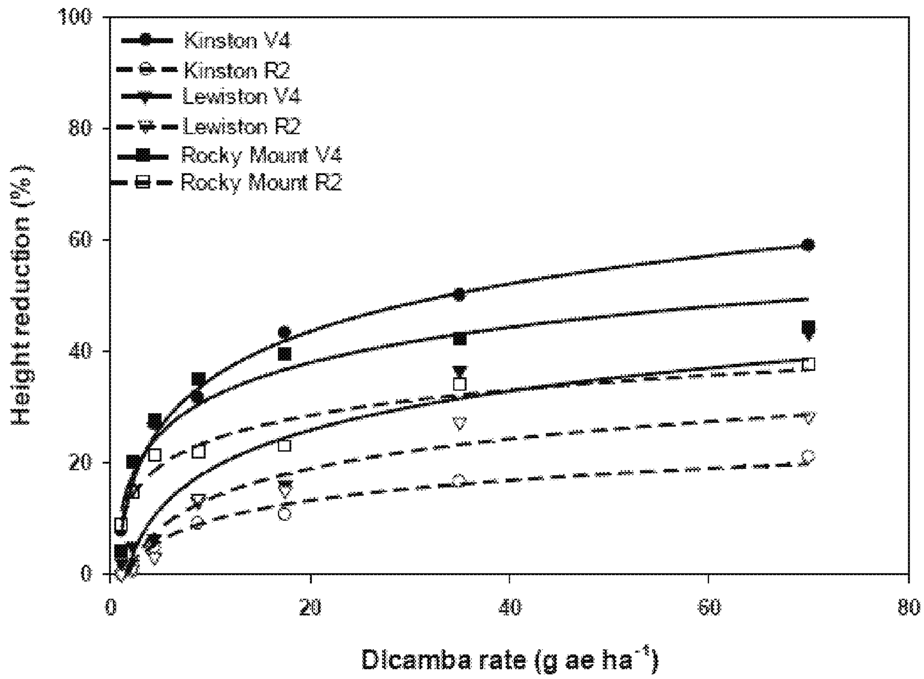

Figure 7. Soybean height reduction as affected by dicamba rate, application timing and environment 14 DAT. Predicted height reduction 14 DAT can be described as: Kinston V4: Y= 6.5+12*ln(abs(x)), r^2=0.99. Kinston R2: Y=-2.4+5*ln (abs(x)), r^2=0.96. Lewiston V4: Y=-4.6+10*ln (abs(x)), r^2=0.85. Lewiston R2: Y=-4+7.7*ln (abs(x)), r^2=0.92. Rocky Mount V4: Y=10+9*ln (abs(x)), r^2=0.88. Rocky Mount R2: Y=9+6.5*ln (abs(x)), r^2=0.93.

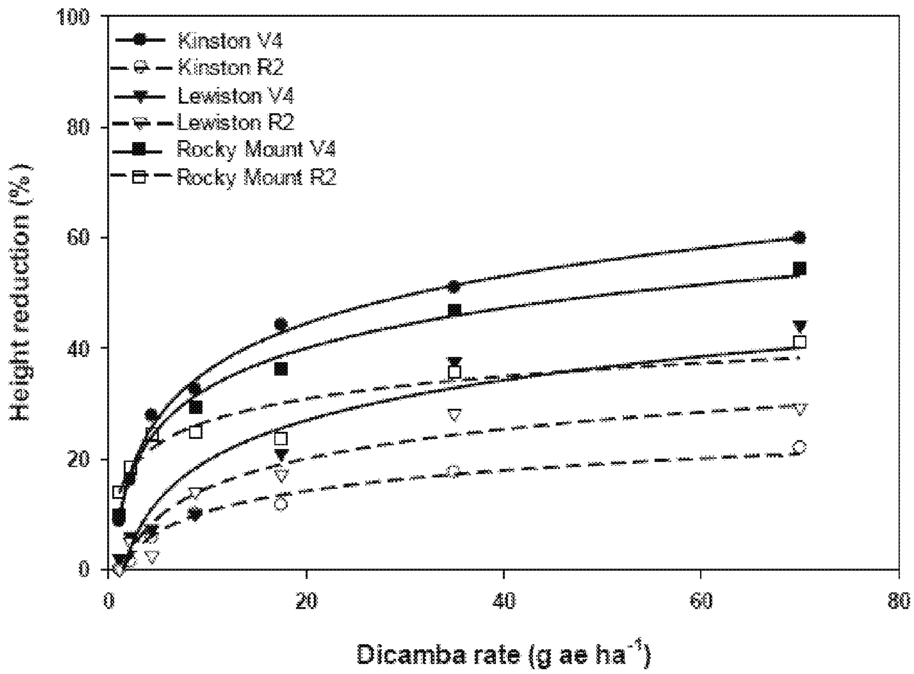

Figure 8. Soybean height reduction as affected by dicamba rate, application timing and environment 14 DAT. Predicted height reduction 14 DAT can be described as: Kinston V4: Y= 7.5+12*ln (abs(x)), r^2=0.99. Kinston R2: Y=-1.9+5*ln (abs(x)), r^2=0.98. Lewiston V4: Y=-4.5+10.5*ln (abs(x)), r^2=0.87. Lewiston R2: Y=-3+7.7*ln (abs(x)), r^2=0.91. Rocky Mount V4: Y=13+6*ln (abs(x)), r^2=0.86. Rocky Mount R2: Y=8.5+10.5*ln (abs(x)), r^2=0.99.

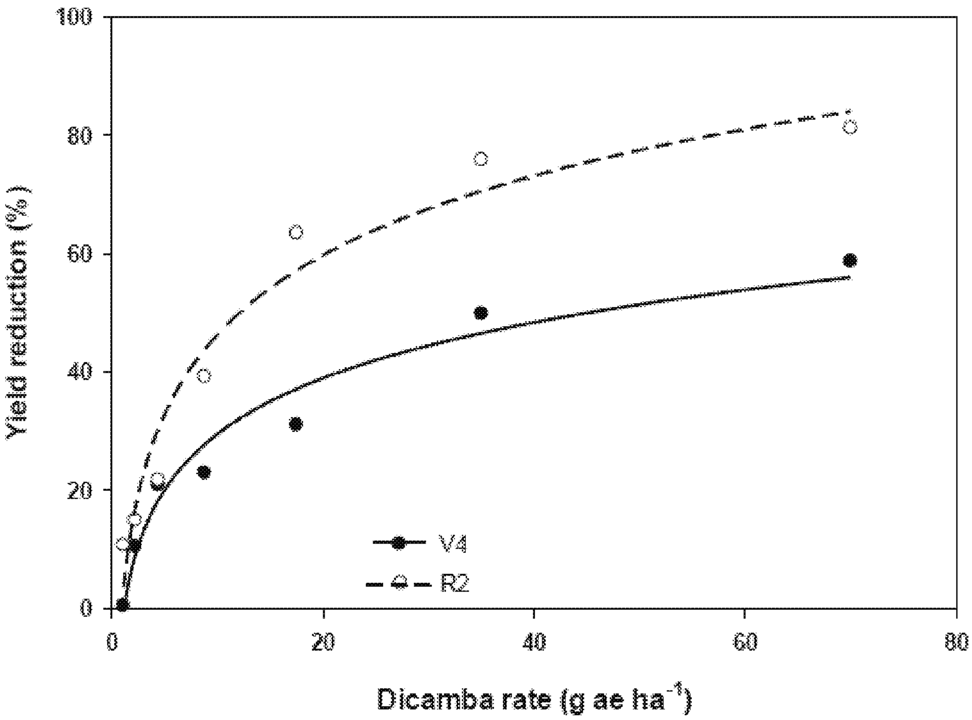

Figure 9. Yield reduction as affected by dicamba rate (1.1-70 g ha^{-1}) and application timing. Predicted yield reduction for V4 application can be described as: Y= -1.8+13.6*ln(abs(x)) , r^2=0.94. Predicted yield reduction for the R2 application can be described as: Y=1.7+19.3* ln(abs(x)), r^2= 0.96.

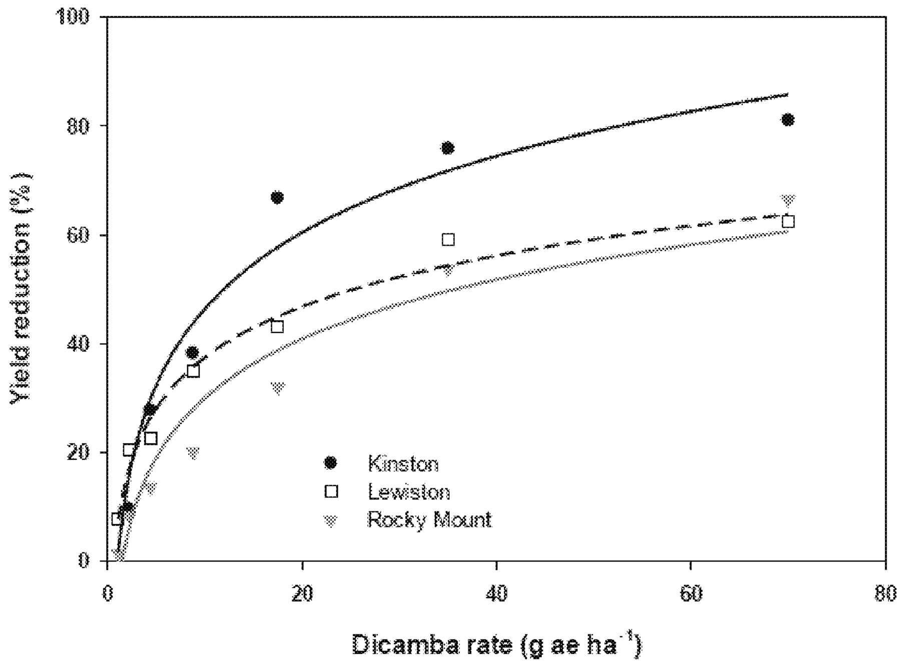

Figure 10. Yield reduction as affected by dicamba rate (1.1-70 g ha^{-1}) and environment.

Predicted yield reduction for Kinston can be described as: Y= -0.2+20*ln (abs(x)), r^2=0.95.

Predicted yield reduction for Lewiston can be described as: Y=6.4+13.5*ln (abs(x)), r^2=0.97.

Predicted yield reduction for Rocky Mount can be described as Y=-6.3+15.7*ln (abs(x)),

r^2=0.93

Deficiencies/Issues Related to Utility for EPA

- The prior history of the field site (i.e., pesticides applied) was not reported
- No details were provided about how cross-contamination was prevented among the plants in the different groups during the application phase (i.e., the controls, the four different treatment levels, the dicamba and 2,4-D products, and the timing of applications to different growth stages). Furthermore, no details were provided on how cross-contamination was prevented after application given that dicamba is volatile.
- It is unclear how well the nominal application rates consistently represent relative exposure to each plant given that a backpack boom spray was used to apply the test material and no direct measurement of the application rate was provided to confirm that the rate cited in the study was accurate.
- The method description does not detail the approach taken to ensure consistency in the identification of various injury effect levels.
- Height measurements were on only four arbitrarily selected plants. It is not clear how they were selected or distributed across the plots.

- It was not stated how many plants were harvested per treatment group for grain yield measurements. It is not clear if yield differences among treatment groups reflected grain yield normalized by plant number or if it also reflected any treatment group differences in the number of plants harvested.
- Data were not presented in a way to discern the yield results from individual trials. The combination of these across growth stage exposures in the results combines the potential variability contributed from multiple sources (e.g., environmental, experimental, and individual measures) in a way that may confound the interpretation of injury to yield relationships.
- Raw data were not requested from the authors for this review, as a result, while regressions are possible, the statistics generated are more reflective of the central tendency of the model and not measurement or response variability.